ORANGE AND LEMON ROT.

By C. W. WOODWORTH.

The present season has been more than usually favorable to the decay of oranges, especially in early shipments. Every year the loss from the rotting of both oranges and lemons is very considerable. The cause of the rot and the precautions that should be taken to avoid the trouble are very rarely understood by those who handle the fruits; and there can be no doubt that a fuller knowledge of the subject would enable growers and shippers to avoid much of the loss. The present bulletin is prepared in response to requests from numerous growers for information on this subject.

The Cause.—The cause of the rot of oranges and lemons is the growth, through their substances, of a mold fungus known scientifically under the name of *Penicillium digitatum.* The growth of this plant within the fruit causes a softening and breaking down of the tissue, a very characteristic change in the flavor of the juice, and sooner or later a very pronounced discoloration of the affected part. The fungus belongs to a genus consisting of a number of well-known species, all having much the same manner of growth and producing decays on various substances. The name "blue mold" applies to the whole group. The best known species is *Penicillium crustaceum*, or, as it is more commonly called, *Penicillium glaucum.* This species is one of the common forms of rot-producing fungi that attack deciduous fruits, but it is probably even better known from its attack upon all manner of substances in the household, such as cooked foods, clothing, etc. While *Penicillium crustaceum* is thus found in a great variety of situations, it appears that *Penicillium digitatum* attacks only citrus fruits, confining itself wholly to these.

Nature of the Fungus.—The form of the fungus while it is growing through the tissue of an orange is that of innumerable fine white threads, known as "vegetative or growing mycelium," the individual threads being called "hyphæ." (Plate 1.) These hyphæ penetrate the fruit in much the same way as the root-hairs of higher plants penetrate the soil. Indeed, they are quite similar, except that the hyphæ are not attached to a more complicated organ like the rootlet from which the root-hair

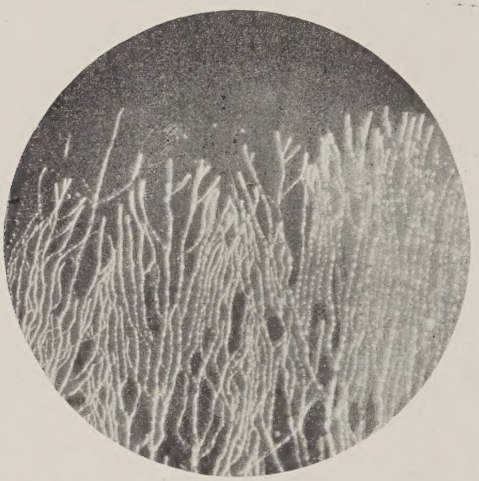

PLATE 1. Vegetative mycelium from a culture of the fungus in water. Very much magnified.

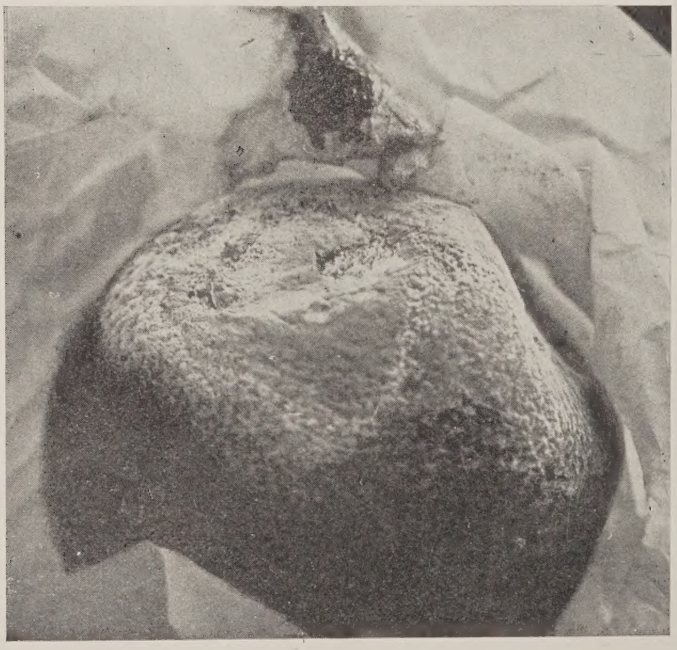

PLATE 2. Rotten orange, partly unwrapped, showing mold in white and blue condition.

springs. After the vegetative mycelium has somewhat exhausted the substances of the fruit, or if the latter becomes too dry for rapid growth, the fungus prepares to develop a form of fruit of its own. Fruiting hyphæ grow outward to the surface of the fruit, or, as is sometimes the case if there is a cavity within the fruit, they grow to the surface of the cavity and there form the *fruiting mycelium*. This is a dense mass of threads, white in color and soft and downy in texture. (Plate 3.) It is this stage of the growth that the growers call "white mold." It is merely a stage in the development of the fungus following the growth of the vegetative mycelium within the fruit, and the fruiting hyphæ are, as it were, the fruit spurs upon which the crop of the fruit of the fungus will be borne. The fruit of the fungus consists of minute, oval bodies, called spores, of dull, greenish-blue color. When they become numerous enough to hide the white mycelium upon which they are borne, the whole surface changes to blue, and it is then called "blue mold." (Plate 2.) The fruiting hyphæ producing the spores first divide into a number of branches, suggesting the name of the species ("digitatum," or fingered), and each of these branches as they increase in length become constricted, and finally divide into a large number of oval fruits, the *conidia-spores*, which for a long time hang together like a string of beads. (Plate 4.) They are easily broken apart, however, and produce then a fine powder that can be carried by the wind, and so are distributed far and wide.

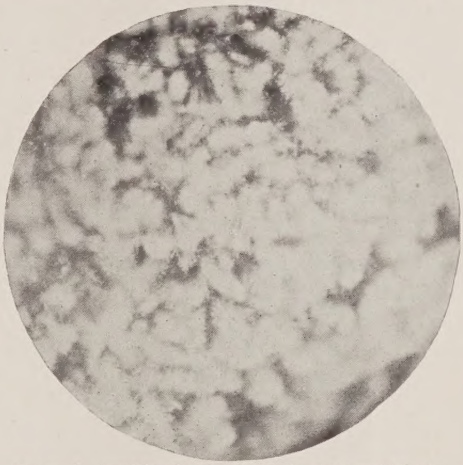

PLATE 3. Fruiting hyphæ in the "white mold" condition. Surface view as seen under the microscope. The same fruit shown in Plate 2.

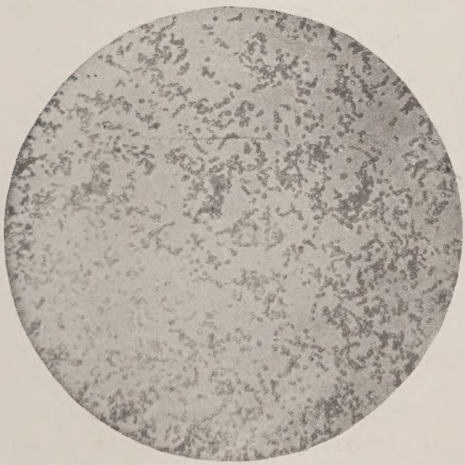

PLATE 4. Conidia-spores—still more enlarged.

There is another form of fruit produced by plants of this genus *Penicillium*, known as the *asco-spores*, being formed in little sacks called *asci*; but they occur only rarely, and, as far as we know, have not been recognized in this species. They doubtless occur, however, and enable the fungus to pass seasons that would kill most of the conidia-spores. The conidia-spore is the means of rapid reproduction, and the only one that is highly significant from the practical standpoint, because it is responsible for practically all of the infection of our fruit with the rot disease.

When and Where It Enters the Fruit.—The rot of citrus fruit is not

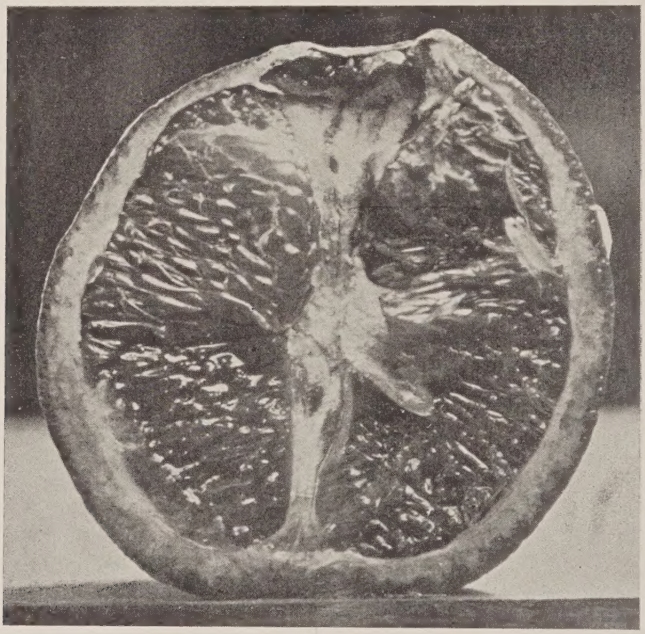

PLATE 5. Navel orange, showing rotten spot.

usually a disease of the orchard. In lemons the infection occurs almost entirely in the curing-house; and in oranges, as a rule, after they are packed and on their way to the East. Navel oranges, however, very often come into the packing-house badly infected by the disease. The trouble begins at the navel end, and may be scarcely visible from without; though commonly a slight split, or perhaps a little gum, will indicate the point of entrance of the fungus. (See Frontispiece and Plate 5.) In this case the trouble clearly arose in the field, and even began before the fruit was ripe. It is usually confined to a limited part of the fruit, perhaps the upper end of one or two sections, and very often produces

spores within the cavity caused by the shrinkage of the affected tissue, so that the affected part may be badly discolored. In any citrus fruit a bad wound of the surface is apt to be followed by the development of the disease in the tissue just beneath, with the general characteristics specified above as occurring in Navels.

In the packing-house or in transit the point of attack may be the navel end, but it is more commonly where two fruits are pressed together. Usually only one of the fruits so touching is affected at first, though after it becomes thoroughly rotted the disease usually communicates to the other. If the conditions are favorable to the growth of the fungus, it may spread from a single affected fruit to all those adjacent, and in time to the whole box.

How It Enters the Fruit.—This disease, being entirely a matter of the fruit and belonging particularly to ripe fruit, evidently always gains its entrance to the fruit from the outside and never from the tree. The conditions necessary to accomplish this are:

First—That the spore of the fungus should rest upon or near the surface of the fruit. It may be carried there by the wind, or by touching decayed fruit upon which the spores are being produced.

Second—Sufficient water upon the surface of the fruit to cause the germination of the fungus.

Third—The right condition of temperature. The fungus will grow in such a range of temperatures, however, that this condition may be considered to be practically always present.

The germination of the spores of the fungus is thus seen to be much the same as the germination of the seed of a higher plant.

The reason that the navel end is particularly liable to the attack of the rot fungus is that in case a drop of moisture finds its way within this structure, it is less liable to rapid evaporation, and so favors the germination of any spores that may also find their way there. The same explanation accounts for the common abundance of this fungus in fruit with broken skin. The point at which moisture will accumulate and remain longest when fruit is sweating after packing, or while it is stored in the packing- or curing-house, is the point where the fruit touches an adjacent fruit; and at this point, therefore, the germination of the fungus most commonly occurs.

PREVENTIVE MEASURES.

From the above review of the manner of growth of the fungus producing the rot of these fruits, it is evident that our preventive measures must lie wholly along one of two lines: either by preventing the spores from gaining access to the surface of the fruit, or by the prevention of the germination of the spores after they are there. For the latter pur-

pose several methods have been employed, usually without knowledge of the reason of their efficiency, and therefore often in a manner to defeat the very object sought. Those that have proven valuable are Refrigeration, Ventilation, and Wrapping.

Effects of Refrigeration.—One of the most available means for absolutely preventing the growth of the fungus, even though abundant upon the surface of the fruit, is to so lower the temperature where it is stored that the fungus will not grow. This method is followed very largely by shippers of green deciduous fruits, who have to contend against the closely related *Penicillium crustaceum.* If sufficient refrigeration is maintained, the fruit will be entirely safe from the attack of the fungus. In the use of refrigeration it should be clearly understood that the cold temperature is likely to condense a large amount of water upon the fruit, and as soon as the temperature is allowed to rise to the point where the fungus can grow, the conditions are extremely favorable for its rapid germination. This has given rise to the belief of many that fruit taken out of refrigeration is much more subject to rot than it was before. The skin may have really become softened by the water during refrigeration, so that this may in some measure be true. The common experience that washed fruit rots worse than that which is brushed dry, may be true for a similar reason. But in any case, the presence of water upon the fruit is always essential for the entrance of the fungus; and if fruit taken from refrigeration is immediately thoroughly dried by arranging for sufficient ventilation, there would be no greater susceptibility on account of the cooling. The use of refrigeration for citrus fruits will probably never be resorted to as extensively as for deciduous fruits, for the reason that the control of rot is not so difficult a matter.

Effects of Ventilation.—The use of ventilated cars, or the ventilation of the curing-house, is chiefly calculated to prevent the rot by carrying off the moisture that may accumulate on the fruit in the sweating process, or on account of the rapid lowering of the temperature. The cooling that is accomplished by the evaporation of this moisture is sometimes thought to act like refrigeration, and may, it is true, slightly decrease the rate of growth of the fungus after it germinates, but can not produce a temperature low enough to prevent its germination and growth. Certainly, the important matter in ventilation is the rapid removal of any condensed moisture that may gather on the fruit. If this moisture is removed promptly enough, so as not to give time for the germination of this mold fungus, the fruit will not decay, but will stay sound until it would ultimately dry up and mummify.

The problem in ventilation, then, is to maintain the mean, and avoid on the one hand too much drying, and on the other the presence of water

for any considerable period upon the surface of the fruit. In small lots this is not particularly difficult, but in larger rooms there is some difficulty in securing a uniform ventilation; and therefore it is desirable, especially in curing lemons, that the temperature be kept as uniform as possible; particularly avoiding rapid lowering of temperature that might result in the deposition of water on the fruit.

Effects of Wrapping.—The practice which is almost uniformly adopted for citrus fruits, and which is rapidly extending also to deciduous fruits, viz., wrapping them in tissue paper, is an extremely efficient means of decreasing danger from rotting. The reason for this is that the paper absorbs water very freely and will take up a very considerable quantity. The paper will have to become very wet before it will give up enough to the spores of the fungus to permit them to germinate, and so it regulates the matter to a large extent; because when the temperature falls the paper merely becomes moist, and when the temperature rises this moisture is evaporated, and if there is fair ventilation it will be carried off and the fruit never become really wet. If the fruit sweats too much, however, owing to poor ventilation or rapid lowering of temperature, the paper will not be sufficient to prevent the accumulation of the water on the fruit and the germination of any spores that may be there. Only within certain limits, therefore, is the wrapping of fruit a preventive of infection by the fungus.

DESTRUCTION OF THE SPORES.

Thus far we have considered measures that have been employed to prevent the germination of the spores. Quite as important a matter is that of decreasing their abundance. This is a subject that has not been given the attention that it should have. I doubt if there is a packing-house in the State in which, in the midst of the season, the odor which is so characteristic of the spores of this fungus is not at once evident to every visitor. It would appear almost surprising if a single fruit could escape the presence of the spores of the mold upon its surface if it passes through some of the packing-houses in which the dust is so filled with them. The means that may be employed to diminish the number of spores in the packing- or curing-house are of three kinds: disposal of infected fruit, disinfection of the house in summer, and the use of sulfur.

Disposition of Decayed Fruit.—It is a common practice to throw decayed fruit in a pile in the immediate vicinity of the packing- or curing-house; and here it continues to decay and produce countless millions of spores, which are freely carried by the wind, and to this is due the thorough infection of the atmosphere, referred to above. There

is no means better calculated to disseminate the disease than this practice. Fruit should never be allowed to become "blue." By the time it reaches the white-mold stage it should either be destroyed by fire, or, what is probably more feasible, be buried. If it is buried deep enough, so that it will not be turned up by plowing, or in any other manner, the decay of the fruit will be completed, and in time the spores of the fungus will disintegrate and the disease will not spread. When the fruit is stored in bins for some days, so that infected fruit will have time to become moldy, these moldy fruits should be removed with great care, so as not to scatter the spores. Attention to this matter can but have a beneficial effect upon the prevalence of the disease.

Summer Disinfection.—In practically all parts of the State the long, dry summer period affords a very available time for the thorough disinfection of the packing-house. The mold spores can be killed by protracted drying, and it should be the practice to so thoroughly air all packing-houses during the hottest and driest part of the summer, that they will be entirely free from the fungus for the beginning of the next year's campaign. In most places this is a very easy operation, and should never be neglected where feasible.

Sulfuring.—When it is not possible to disinfect the house in the summer by drying, as suggested above, or by whitewashing, it may be possible to destroy the spores by the free use of sulfur. This is also possible during the actual packing season. The sulfur should be burned so that the fumes will come in contact with every part of the inside of the packing- or curing-house. Usually these buildings are not tight enough to permit of very thorough work, so that no prescription of the amount to use can be safely made. The material is not expensive, so that the best policy is to use it very liberally whenever the presence of the fungus in quantity is known or suspected to exist in the house.

ORCHARD PRACTICE.

A great deal of fruit undoubtedly goes into the packing-house already covered with the spores of this rot-fungus. As much carelessness in the disposal of rotten fruit is seen in the orchard as has been pointed out above as occurring about the packing-house. Rotten fruit is very commonly allowed to fall upon the ground, and is turned under with the plow, to be turned up again in subsequent cultivations. In almost any orchard in which the disease is prevalent, one would not have any difficulty in finding oranges or lemons, covered with quantities of mold-spores, lying upon or just beneath the surface of the ground, from which they may be blown over the fruit with the dust.

It is not only the Navels that are thus endangered; but these fruits